

CONCRETE
SHELL AND BARREL
ROOFS

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Cement and Concrete Association : 52 Grosvenor Gardens SW1

The design of the thin curved concrete roof is an adaptation of the principle which gives strength and rigidity to the sea shell. Chief credit for the mathematical researches which made imitation possible belongs to Carl Zeiss of optical fame. His elaborate and painstaking calculations were, however, of little more than academic interest until there was readily available a material possessing adequate qualities of tension and compression for constructional purposes. The advent of reinforced concrete gave the theory a practical value.

Experiments were made on the Continent and one of the outstanding early achievements was the Dusseldorf Planetarium built in 1926 by Dyckerhoff and Widmann. Other notable examples were the Leipzig Market, the Market Hall at Budapest and the Rheims Railway Station.

By 1931 patent rights had been taken out in Great Britain by Carl Zeiss and Ulrich Finsterwalder. The sole licensee was T. A. Chisholm of "Chisarc" and Shell "D" who still retains the sole licence for Great Britain. The first contract to be completed was that for the Doncaster Municipal Airport in 1936, the work being carried out by J. H. Metcalf Brothers, acting under licence for "Chisarc" and Shell "D", who prepared the reinforced concrete design. This was followed by railway sheds at Liverpool, platform roofs in Surrey, a bus garage for Manchester Corporation and some smaller structures.

During the war this method of roof design was largely used in the United States as a means of effecting economy in steel. It thus served a most important purpose as steel shortage coincided with a period in which a rapid expansion of building was essential to the national interest. Outstanding examples of such roofs were the hangars for naval barrage balloons at San Diego, storage warehouses in Ohio, and an industrial building for the Armstrong Tile and Rubber Company at Natchez, Miss.

In this country, development was retarded in the war years, but some structures were completed, including a works canteen for May and Baker at Dagenham, Essex, which is illustrated on page 2 and a contract at Bicester for the Director of Fortifications and Works covering approximately 9 acres of floor area.

Since the war ended there has been an increasing use of shell and barrel roofs both at home and overseas and a number of the structures are described in the following pages.

The chief advantage of the method is its economy in the use of materials. A striking illustration of this is provided by the fact that the roof over Leipzig Market, built in 1929, encloses an area three and a half times that covered by the famous dome of St. Peter's in Rome, yet the Leipzig construction necessitated the use of only one-fifth of the weight of the material used for St. Peter's.

The shell concrete roof has an appearance thoroughly in keeping with modern trends in architecture and is not difficult to construct, especially if it is so designed as to permit the use of standardized forms.

Canteen at Dagenham

May and Baker Limited

ARCHITECT :

Edward D. Mills, F.R.I.B.A.

ENGINEERS :

Barrel Vault Roofs (Designs) Limited.

GENERAL CONTRACTOR :

Dix (Builders) Limited.

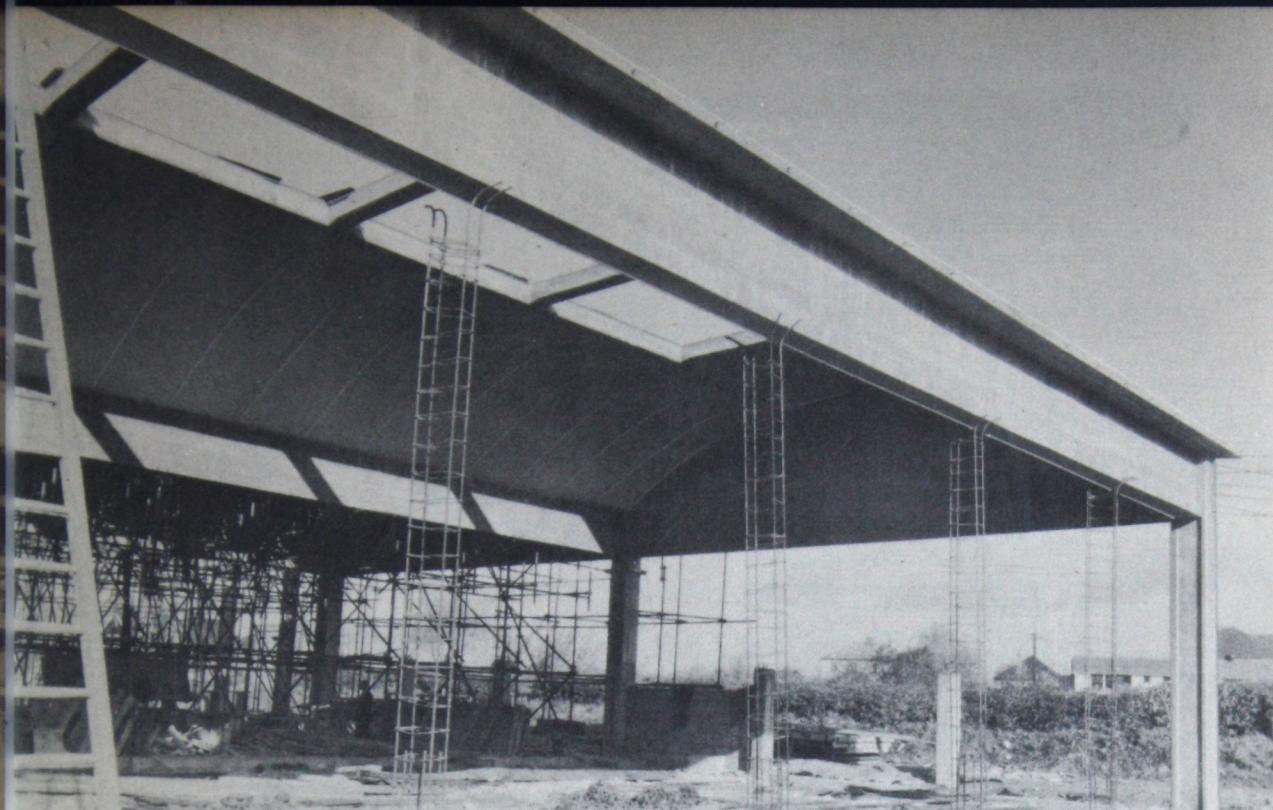
BARREL VAULT ROOFING : F. Bradford and Company Limited.

REINFORCEMENT SUPPLIERS : "Twisteel" Reinforcement Limited.

The roof of the main hall, 48 ft. \times 120 ft., consists of five reinforced concrete barrel vaults 48 ft. long, each with a chord width of 25 ft. supported on reinforced concrete columns. The barrels are $2\frac{1}{2}$ in. thick at the top.

Cheerful, modern and economical, a roof of this type is excellently suited to a building of a recreational character.





Great freedom in planning can be given with supports 50 ft. or 60 ft. apart in either direction.

Factory at Knowle, Bristol

John Hall and Sons Limited

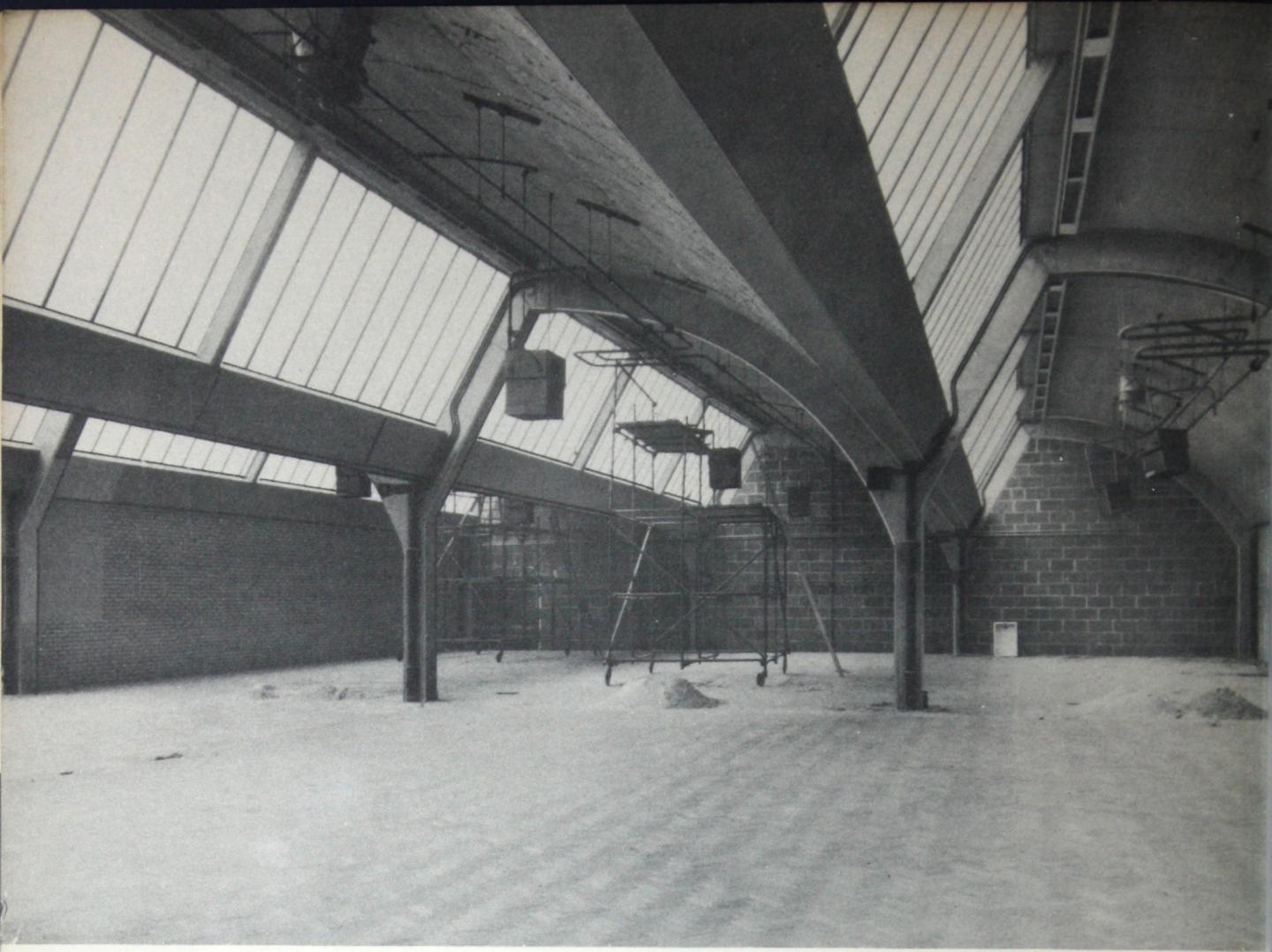
ARCHITECTS : W. H. Watkins, F.R.I.B.A. and Partners.
CONTRACTORS AND DESIGNERS : Christiani and Nielsen Limited.

The main building is 150 ft. long \times 122 ft. wide and is covered by a thin curved concrete roof, divided into three barrels with chord widths of 40, 40 and 42 ft. Diaphragm beams are provided at the gables and at two intermediate points dividing the 150 ft. long barrels into two sections 60 ft. long and one section 30 ft. long. The 30 ft. sections are in the centre of the barrels to facilitate the arrangement of the equipment in the building, and to provide for future extensions which are to take the form of two additional sets of barrels 60 ft. long, arranged symmetrically with those now being constructed.

The clear height under the diaphragm beams and the edge beams is 15 ft. in the case of the 40 ft. chord width and 20 ft. in the case of the 42 ft. chord width barrels. The slab thickness is 3 in. throughout.

At the crowns of the barrels skylights of 9 ft. span are arranged for almost the entire length of the building. To transfer the forces from one side of the skylights to the other, they are provided with 1 ft. \times 1 ft. edge beams and 1 ft. \times 1 ft. transversal beams spaced at 12 ft. centres.

The barrels are insulated underneath with $\frac{1}{2}$ in. Celotex boards and the roof covering is to be bituminous felt.



Factory at Enfield

Reeves and Sons Limited

Northlight construction presents no special difficulty and the freedom from interference by the structural members helps to give an almost perfect daylight effect.

ARCHITECT : A. G. Porri, F.R.I.B.A.
ENGINEERS : Barrel Vault Roofs (Designs) Limited.
CONTRACTORS : Sir Robert McAlpine and Sons Limited.
REINFORCEMENT SUPPLIERS : "Twisteele" Reinforcement Limited.

This building is the first in this country to have barrel vault Northlight roofing.

The width of the bays is 24 ft. 6 in. and the stiffening ribs which are 57 ft. apart, follow the curve of the barrel and form portal frames with the columns. The shell, 3 in. thick, is lined with insulating board on the soffit. Two layers of bituminous felt are applied to the exterior.

Bus garage at Wythenshawe

ARCHITECT : G. Noel Hill, F.R.I.B.A., M.T.P.I.

CONTRACTORS AND REINFORCED CONCRETE DESIGNERS : J. A. King and Company Limited, operating under licence issued by " Chisarc " and Shell " D " who prepared the reinforced concrete design.
Their consulting engineer is H. G. Cousins, B.Sc. (Lond.), M.I.C.E.

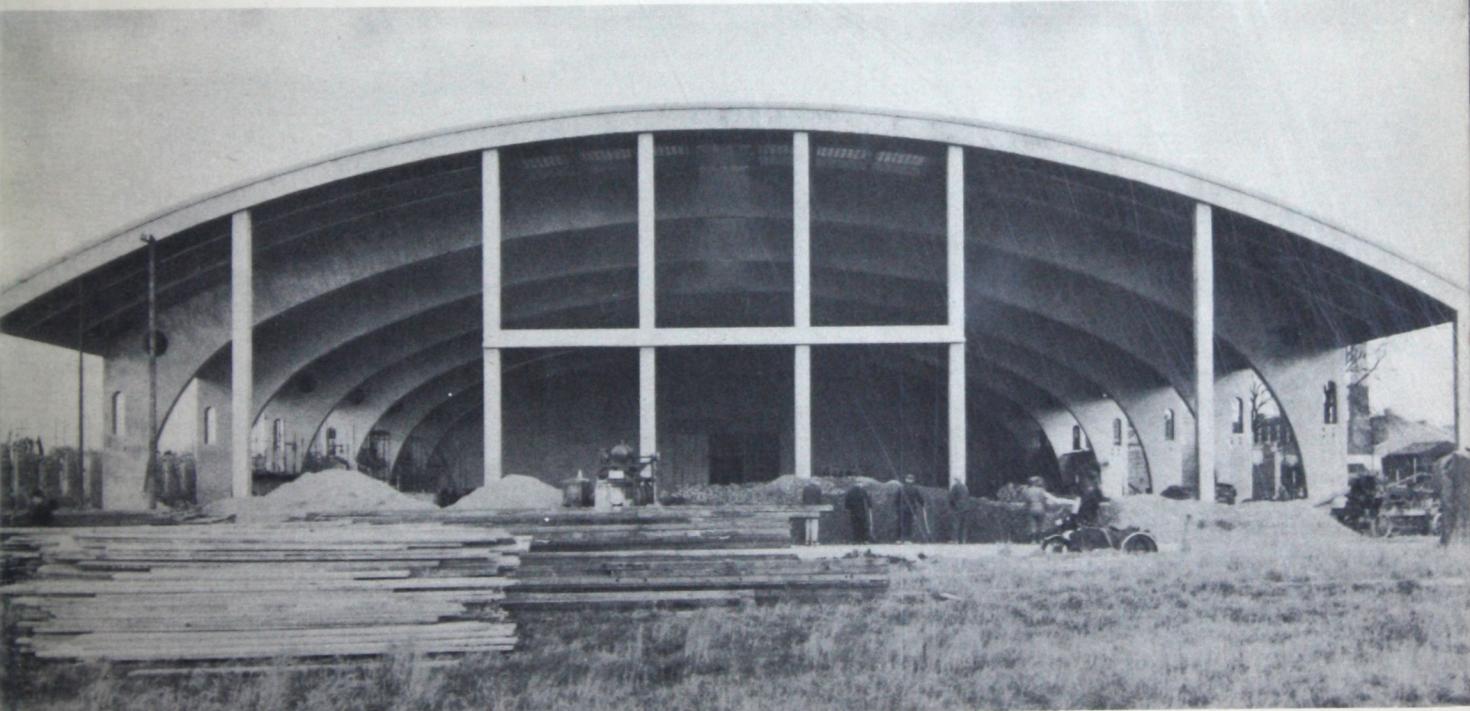
Although work on this building commenced early in 1939 it was not completed until 1941 because of delays caused by the war.

In the main garage a single shell roof $2\frac{3}{4}$ in. thick, with a radius of 180 ft., spans between hinged arches. These arches, of 168 ft. span, are at 42 ft. centres and two intermediate beams are placed between each arch and parallel to the arches.

The roof in the repair hall has seven vaults, each of a chord width of 33 ft. and a length of 132 ft. There are special roof lights throughout.

The washing room which is an annexe to the repair hall is roofed with four barrel vaults, each of which has a chord width of 16 ft. 6 in. and a length of 57 ft.

The saving in weight which results from the use of a curved slab only $2\frac{3}{4}$ in. thick. makes it possible to construct a building 168 ft. clear span with economy.



Factory at Dagenham

May and Baker Limited

ARCHITECT :

Edward D. Mills, F.R.I.B.A.

ENGINEERS :

Barrel Vault Roofs (Designs) Limited.

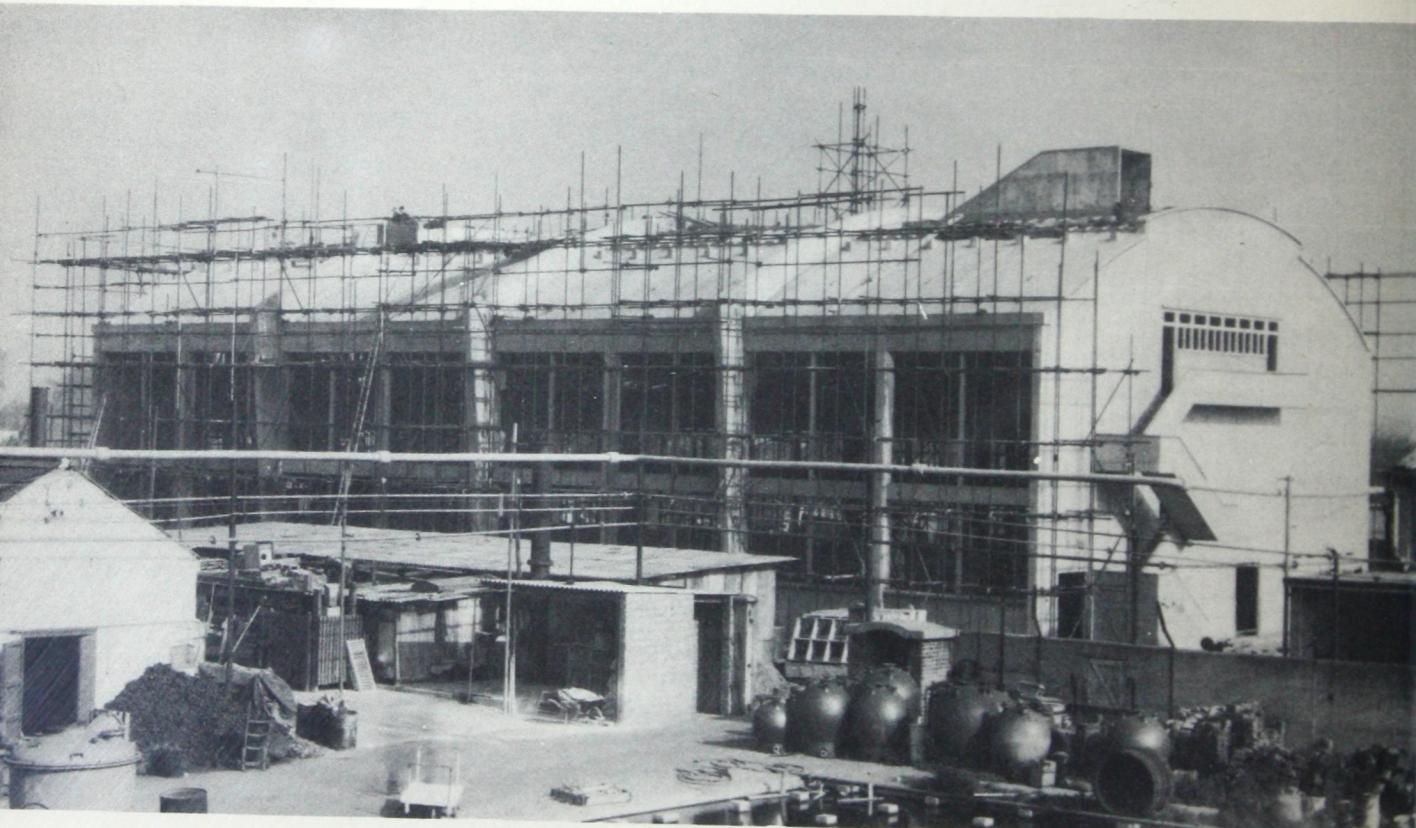
CONTRACTORS :

Holland & Hannen and Cubitts Limited.

REINFORCEMENT SUPPLIERS : "Twisteel" Reinforcement Limited.

This is a single-storey building 144 ft. long with a barrel roof of 63 ft. 6 in. chord width. There are three main portal frames at 36 ft. centres and two solid gable walls supporting the barrel. The barrel is broken by purlins which carry glazing and by flat slabs which can be removed for upward plant extensions. The barrel is $2\frac{1}{2}$ in. thick and covered with bituminous emulsion. The soffit is lined with insulating board and plastered.

The chord width of this barrel is 63 ft. 6 in. The stiffening beams are entirely outside the shell, giving a clear ceiling for the whole length of 144 ft.





Shell construction in its simplest form—the 3 in. curved slab, with a chord width of 31 ft. 6 in.—carries itself between the outer and central stiffening ribs. Only at the sides are the 55 ft. span edge beams required.

Timber Sheds at Speke, Liverpool

ENGINEER : W. K. Wallace, C.B.E., M.I.C.E.

CONTRACTORS : Frank Haslam Limited, operating under licence issued by " Chisarc " and Shell " D " who prepared the reinforced concrete design.

This open shed, 348 ft. wide \times 110 ft. long, was completed in 1937. The roof consists of eleven shells, with an average chord width of 31 ft. 6 in., with a rise of 5 ft. 9 in. at the centre. The height of the shed from ground level to the underside of the crown of the shell is 26 ft. 6 in. The shells are supported at each end and at an intermediate point by rigid frames.

The thickness of the shell is 3 in., except for an increase to $4\frac{1}{2}$ in. over the intermediate frames. In the valleys the concrete is thickened to a maximum depth of 12 in.

The photograph gives an idea of the ease with which duplication can be employed to economize in the use of metal shuttering.



Cereal Factory at Dagenham

ARCHITECT :

W. R. Glen, F.R.I.A.S.

ENGINEERS AND DESIGNERS :

The Liversedge Reinforced Concrete Engineering Company Limited.

Work began on this factory for cereal products during 1947. The floor area, excluding the boiler house and chimney and ancillary buildings, is approximately 45,000 sq. ft.

The main factory area is divided into "ARCH-SPAN" standard bays each 40 ft. x 25 ft. chord width, headroom 12 ft., to suit the arrangement of the factory production lines.

The "ARCH-SPAN" roof slab is $2\frac{1}{2}$ in. thick at the crown. Normal round mild steel bar reinforcement is used. Standard "ARCH-SPAN" metal forms and supports are used throughout to permit the maximum re-use of built-up sets of forms.

The roof is waterproofed with 2-layer bitumastic felt, and roof lights of aluminium bar construction are incorporated to ensure adequate light. A waterproof expansion joint divides the whole building into suitably sized areas.

Bakery at Drayton, Hants.

Portsea Island Mutual Co-operative Society Limited

ARCHITECT :

H. G. Wilding, L.R.I.B.A., P.A.S.I.

ENGINEERS :

Barrel Vault Roofs (Designs) Limited.

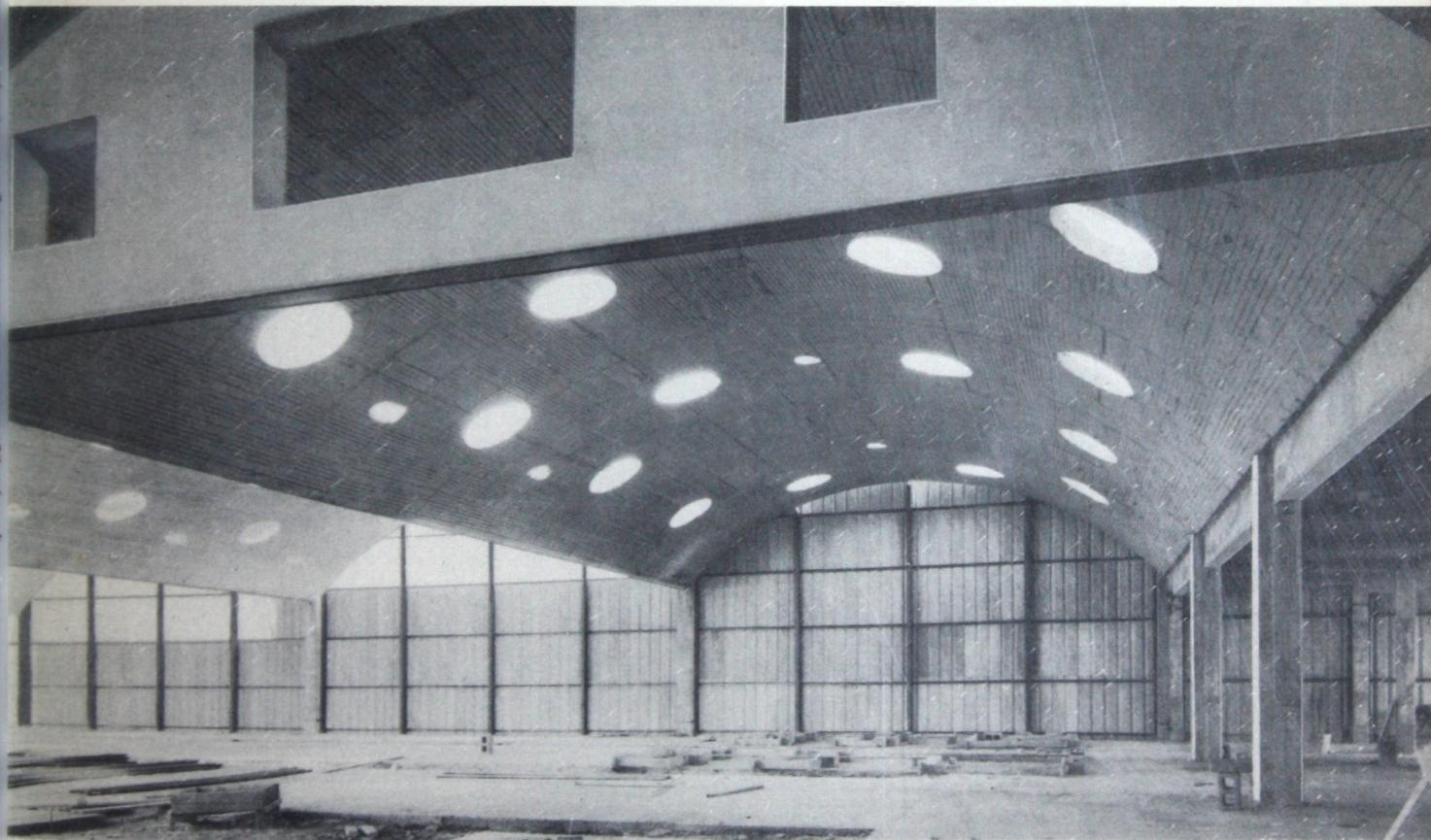
CONTRACTORS :

Portsea Island Mutual Co-operative Society Limited,
Building Department.

REINFORCEMENT SUPPLIERS : "Twisteel" Reinforcement Limited.

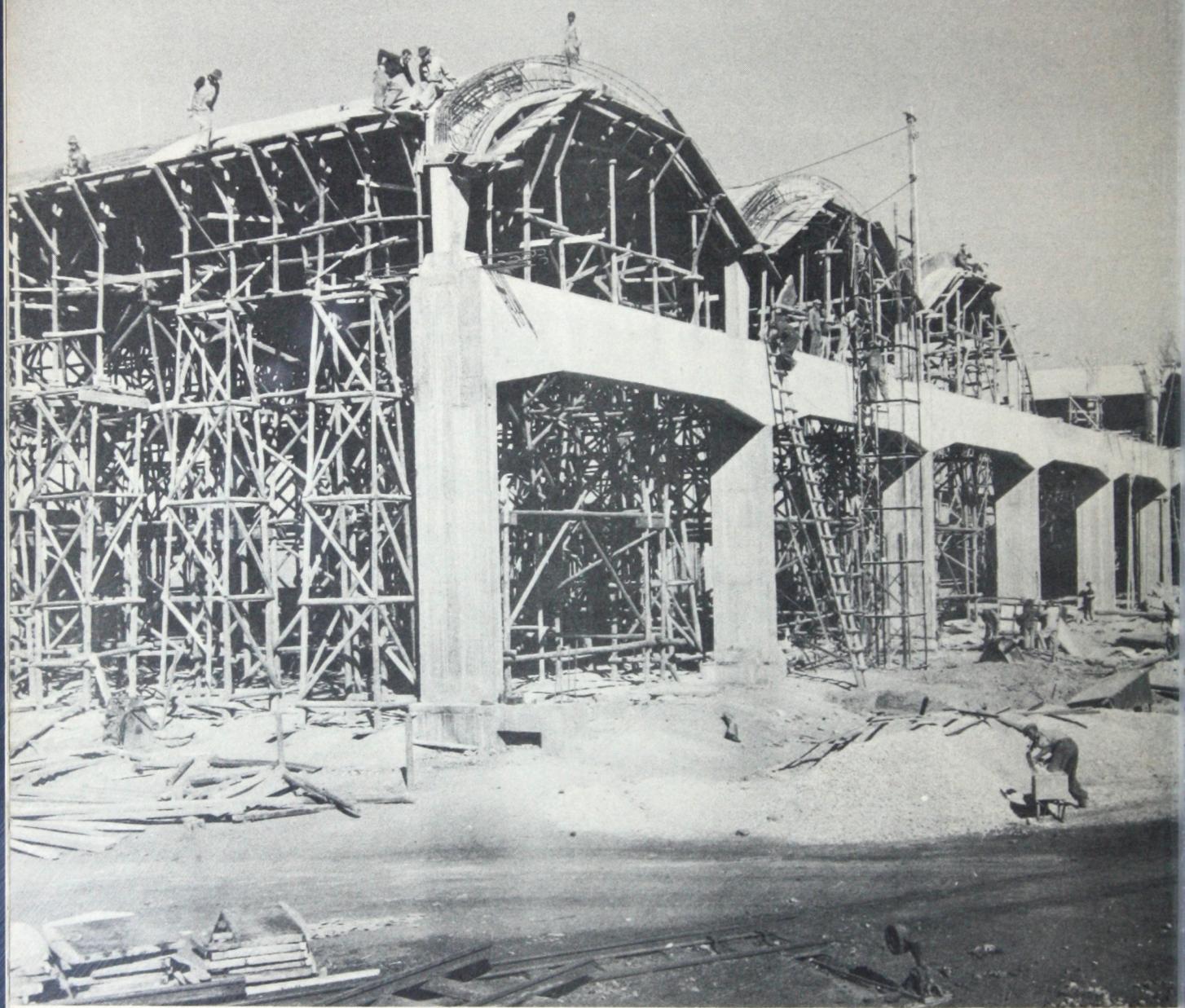
All the four barrels have a chord width of 44 ft. and a length of 80 ft., with a radius of curvature of 30 ft. and a thickness of $2\frac{1}{2}$ in. The roof lights are 4 ft. in diameter.

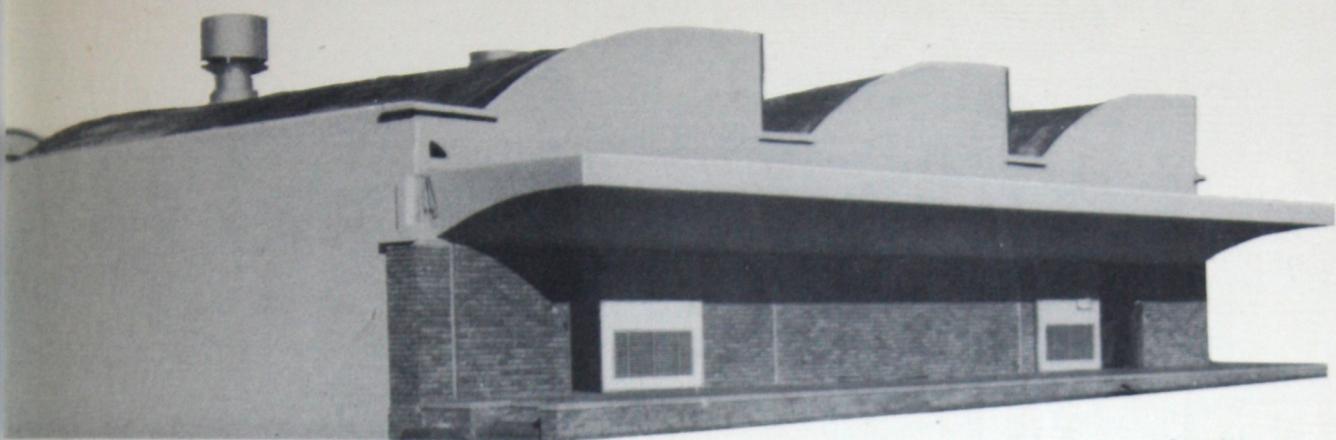
The stiffening beams at the ends of the barrel can be either below or above the slab. Condensation can be guarded against by covering the formwork with insulating board before the concrete is placed.



Examples from South Africa

CONTRACTORS : Roberts Construction Company (Pty.) Limited.





The Northlight type of roof, common in this country, is given vertical glazing in Africa, and may be either of the usual form (above) or the curved slab may be normal to the glazing (on the right) which has the advantage that all rain is collected and can be carried away by piping concealed in the columns.

Provision for crane rails and future extension is a simple matter (opposite) while the use of timber towers to support the formwork is of interest.



Factory at Brynmawr, South Wales

ARCHITECTS : Architects' Co-operative Partnership.

CONSULTING ENGINEER : Ove N. Arup.

CONTRACTORS : Holland & Hannen and Cubitts Limited
Gee, Walker and Slater Limited.

Main production area

The nine domes which form the roof of this section are rectangular in plan each measuring 83 ft. by 63 ft. 9 in. The reinforced concrete is $3\frac{1}{2}$ in. thick, with $2\frac{1}{2}$ in. of insulating cell concrete on top covered by roofing felt finished with Derbyshire spar chippings.

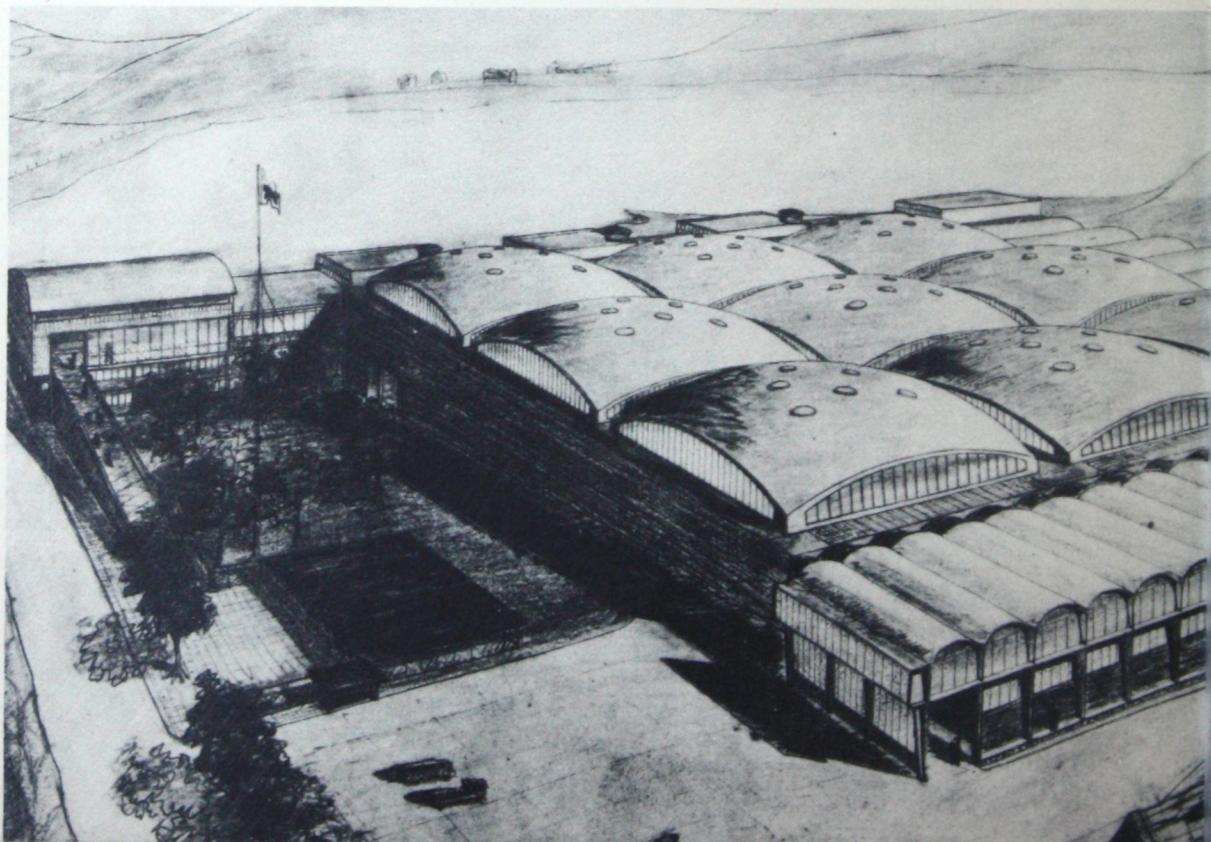
Drug room and mill room

The cylindrical shell roofs have a length of 44 ft. $7\frac{1}{2}$ in. in the drug room and 63 ft. 9 in. in the mill room. The chord widths of the roofs are respectively 12 ft. 9 in. and 31 ft. $10\frac{1}{2}$ in.

South block

With the exception of the entrance hall, which has a cylindrical shell roof, this section is a reinforced concrete frame structure with cross reinforced floor and roof slabs. The cylindrical shell is $2\frac{3}{4}$ in. thick with $2\frac{1}{2}$ in. of insulating cell concrete on top. It is 67 ft. in length and spans 38 ft. 3 in. between columns.

This perspective shows the main factory from the North-East and illustrates the extent to which both the dome and cylindrical shell forms are being employed.





Hangar at Karaechi

The Civil Airport

CONTRACTORS AND REINFORCED CONCRETE DESIGNERS :
J. C. Gammon Limited, Bombay, and Pre-Stressed Concrete Company Limited.

The hangar at the Civil Airport, Karachi, together with two others at Meerut, was completed in 1943. These hangars all have clear internal dimensions of 396 ft. by 130 ft. and a clear height of 35 ft. above the floor. The roof in each case spans over the 130 ft. length without intermediate support and is carried at the rear on a row of twelve reinforced concrete columns spaced 35 ft. apart, braced together and founded on isolated footings. At the front end it is carried over the 190 ft. clear door openings by two independent prestressed reinforced concrete beams. These two prestressed reinforced concrete beams carry five isolated loads of 93 tons each. The structure of the roof consists of two units, each of five continuous cylindrical shells, spanning between the end supports described above. Each shell has a chord width of 35 ft. and a thickness of $2\frac{1}{2}$ in., and is stiffened at the edges with a deep reinforced concrete rib, or tie beam. The cylindrical shells and ribs act together as a freely supported structural unit spanning between the end supports in the 130 ft. direction. The tie beams and door beams are prestressed by means of sheathed cables with special anchorage cones designed on the Freyssinet system.

This photograph, taken while the hanger was still under construction, shows how admirably the shell roof is suited to buildings requiring a large area of clear floor space.

Photograph: The Institution of Civil Engineers.



The use of thin curved slab construction between cantilevers 25 ft. apart is as effective as if the slab construction were carried by beams and supported at both ends.

Railway station in Surrey

CONTRACTORS FOR CONCRETE ROOF: G. T. Crouch Limited, operating under licence issued by "Chisarc" and Shell "D", who prepared the reinforced concrete design.

The Chief Engineer to the British Railways, Southern Region, is Mr. V. A. M. Robertson, C.B.E., M.C., M.I.C.E.

The platform length at this station is 540 ft. of which 200 ft. is covered by a "Chisarc" reinforced concrete roof. Cantilever ribs, with an overhang of 14 ft. are provided at intervals of 25 ft. The reinforced concrete is 3 in. thick.

Tobacco warehouse at Belfast

Gallaher Limited

ARCHITECT : Ernest A. Newton, M.B.E., F.R.I.B.A., F.R.S.A.

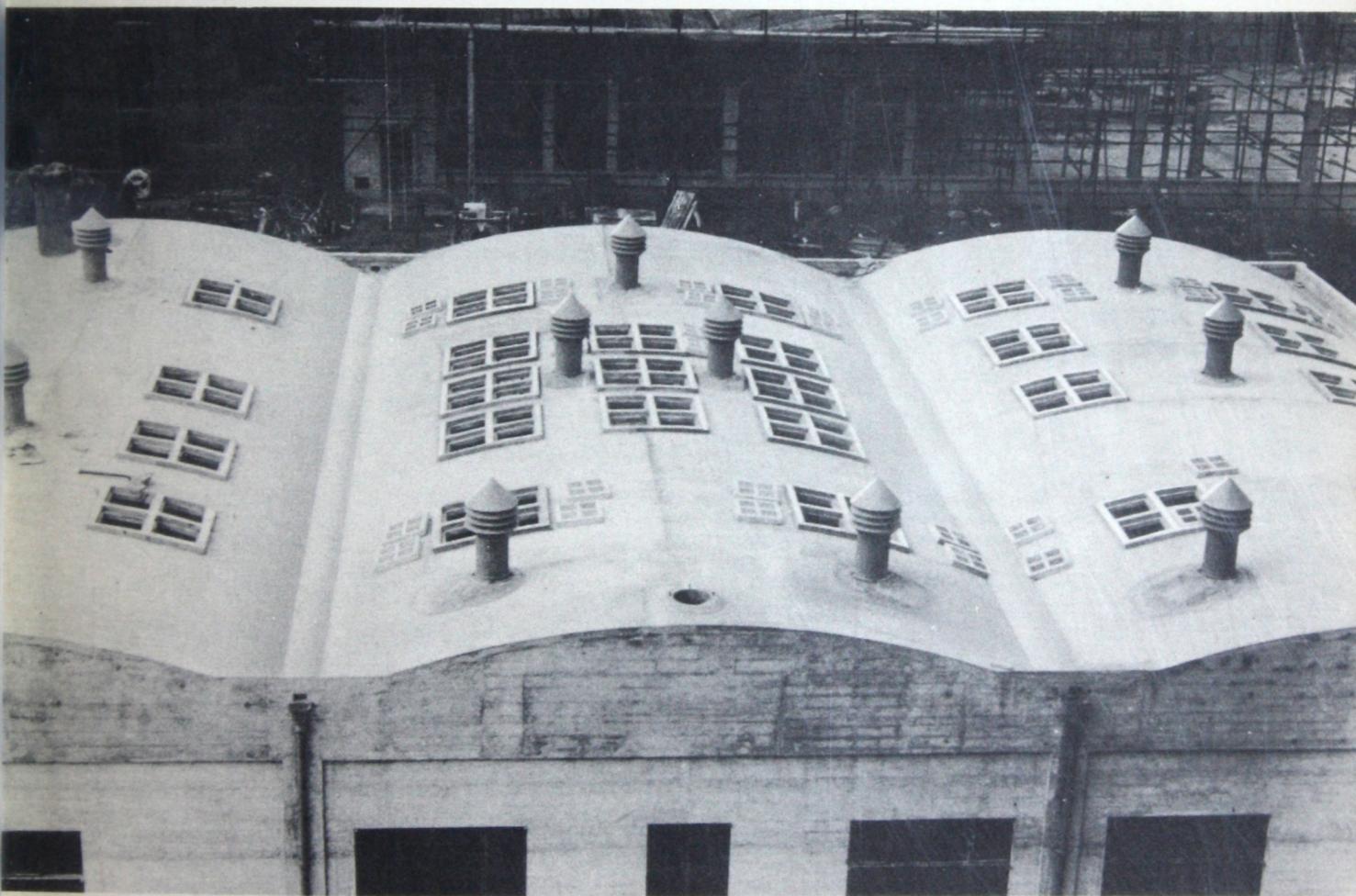
CONSULTING ENGINEER : H. G. Cousins, B.Sc.(Lond.), M.I.C.E.

CONTRACTORS : McLaughlin and Harvey Limited.

REINFORCED CONCRETE DESIGNER AND LICENSEES : " Chisarc " and Shell " D. "

The roof is 420 ft. \times 163 ft. and the roof thickness $2\frac{3}{4}$ in.
Chord widths are 38 ft. and 30 ft.

The warehouse roof, with top-lighting, ventilators and drainage channels,
photographed before the application of the waterproof layer.



Warehouse at Silvertown

Burt Boulton and Haywood Limited

CHIEF ENGINEER TO BURT BOULTON AND HAYWOOD LIMITED : A. E. N. Weeks.

ENGINEERS :

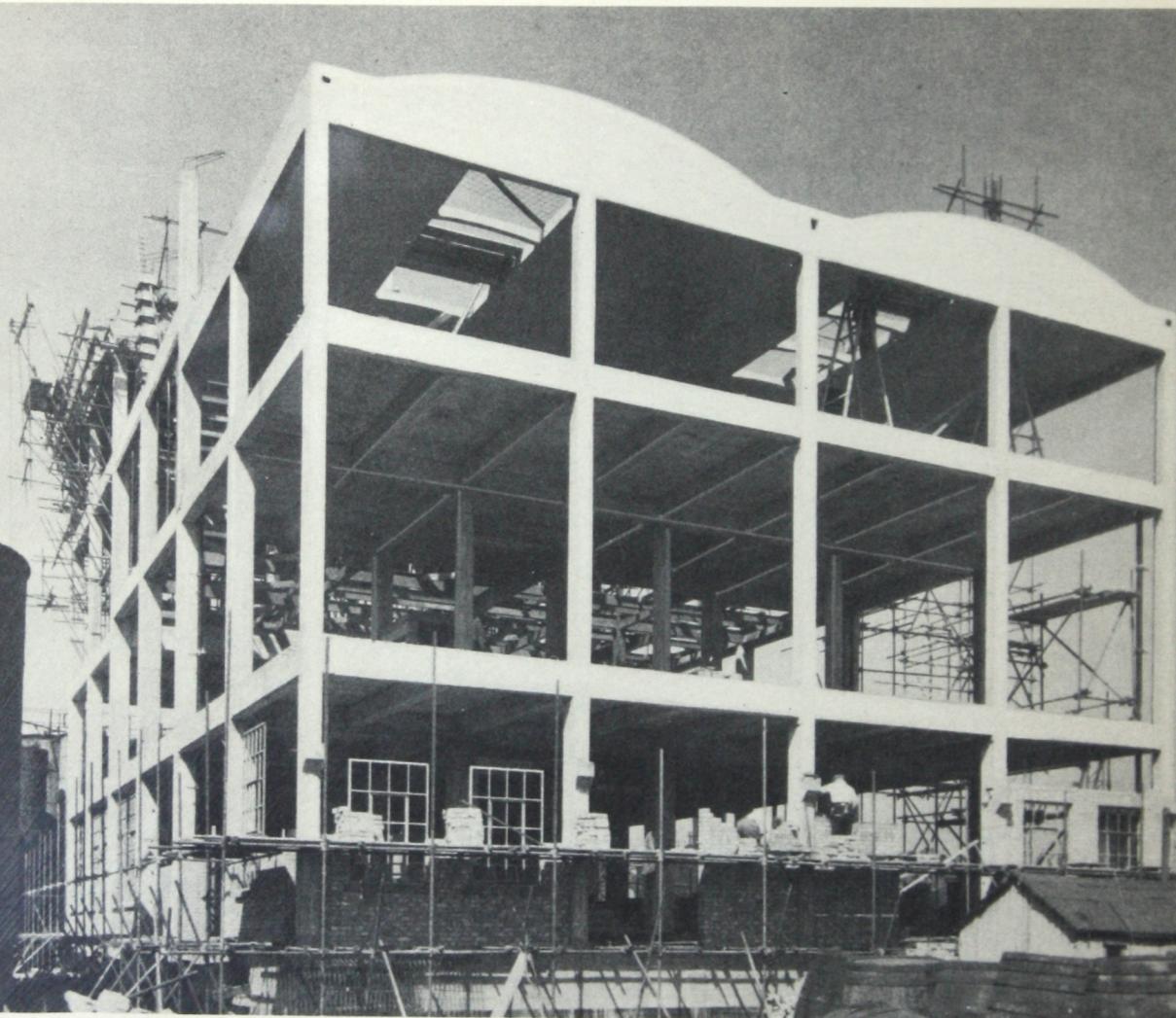
Barrel Vault Roofs (Designs) Limited.

REINFORCED CONCRETE CONTRACTORS : F. Bradford and Company Limited.

REINFORCEMENT SUPPLIERS : "Twisteel" Reinforcement Limited.

This multi-storey reinforced concrete frame building is roofed with two barrels. The chord widths are 30 ft. and the length of the barrels is 36 ft. The shell thickness is 2½ in. Natural lighting is by lantern lights in the centre of the shell.

So great is the inherent strength of this type of roof that large openings may be incorporated to provide for natural lighting.



The Cement and Concrete Association

Users of cement and concrete have available to them a free and impartial service of technical information and advice based equally on long practical experience and on the findings of a modern Research Station. Inquiries should be sent to the Cement and Concrete Association, 52 Grosvenor Gardens, London, SW1 (or in the case of Scotland to 22, Rutland Square, Edinburgh) where they will be answered by its research, its architectural or its engineering officers. If it is not possible to deal with a problem by correspondence, arrangements can often be made for a technical officer of the Association to visit the work in progress. This service is an important part of the work of the Association, which comprises, in addition to research, education, the promotion of better concreting practice, the study of new uses of the material and the publication of both popular and scientific booklets and bulletins.

The Association does not engage in the manufacture or sale of cement. It is a non-profit-making body, financed through a levy by the companies listed below:—

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